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ASTRONOMY

BV PHOTOMETRY OF THE ULTRACOMPACT BINARY STAR GP COM

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Abstract

We present optical B and V band photometry of GP Com – an ultracompact binary consisting of an accreting white dwarf and helium secondary component. Our data set contains 7.7 hours observations in V band with the 2.0m telescope and 2.9 hours simultaneous observations in B and V bands with the 1.5m telescope of the Rozhen National Astronomical Obsevatory, Bulgaria. The observations cover ≈ 13 orbital periods.

We find an orbital modulation with amplitude 0.04–0.05 mag in B and V bands. Adopting that it is due to a bright spot, we estimate its temperature $\approx 19700 \pm 3000$ K. We estimate mass accretion rate onto the white dwarf of about 2×10^{-12} $M_\odot$ yr^{-1}, consistent with the predicted rate for a cool donor.

The data are available on Zenodo: `zenodo.org/records/18768211`.

Key words: stars: novae, cataclysmic variables – accretion, accretion discs – stars: individual: GP Com

1. Introduction. GP Com (G 61-29) is a 16*th* magnitude star in the constellation Coma Berenices located at a distance 72.7 pc from the Earth [1]. It has orbital period [2] $P_{orb} = 46.57$ min and is one of the brightest members of the group of AM Canum Venaticorum (AM CVn) stars.

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AM CVns are binaries with short orbital periods, in which the primary star is a white dwarf accreting from a He-rich secondary. They are subclass of the cataclysmic variables family and have spectra rich in helium-emission lines. AM CVns are sometimes named interacting binary white dwarfs and are expected to be sources of persistent gravitational wave radiation. Their orbital periods range between 5 and 65 minutes [3, 4] and till now of about 120 objects are found and confirmed [5].

Here, we report optical photometric observations of GP Com in Johnson B- and V-bands, study the orbital modulation and estimate the temperature of the hot spot and the mass accretion rate.

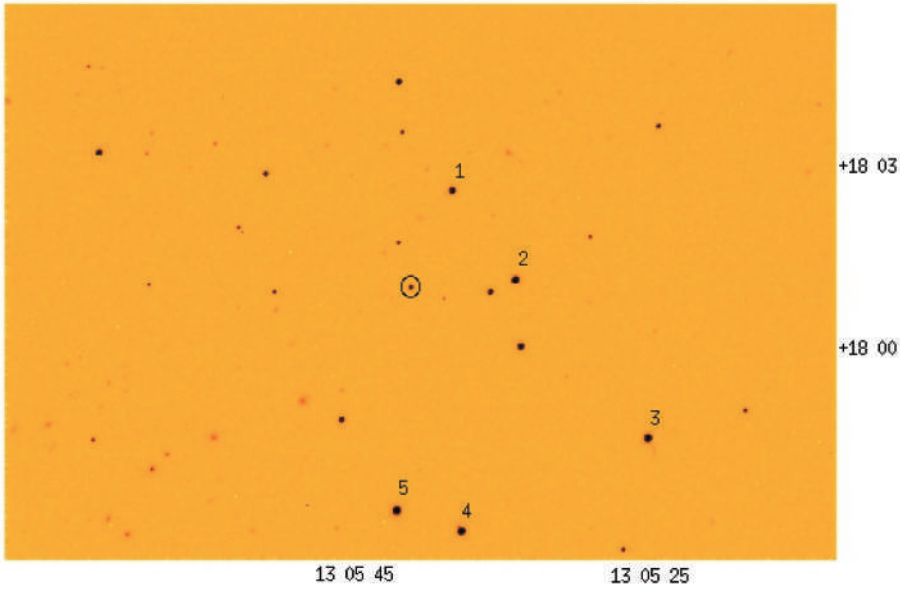


Fig. 1. V band image of the field around GP Com, obtained with the 1.5m telescope of NAO Rozhen on 2025-11-14 UT 03:24, exposure time 60 s. GP Com is marked with circle. The coordinates and magnitudes of the comparison stars can be found in Section 2

2. Observations. The observations were secured with the 2m RCC telescope and with the 1.5m AZ1500 telescope [6] of the Rozhen National Astronomical Observatory, Bulgaria. Both telescopes are equipped with CCD cameras. The field of view of the 2m telescope is a circle with diameter 14 arcmin, of the 1.5m telescope – a rectangle 12×8 arcmin. As a first step we identified a few stars in the field (see Fig. 1) that can be used as comparison stars:

No.	RA	Declination	B	V
# 1	13 05 39.4	+18 02 45	15.170	14.249
# 2	13 05 34.6	+18 01 21	14.66*	13.762
# 3	13 05 24.5	+17 58 54	14.155	13.399
# 4	13 05 37.0	+17 57 07	14.623	13.699
# 5	13 05 41.6	+17 57 22	13.566	13.039

They are all located at angular distance less than 5 arcmin from GP Com. The B and V magnitudes are synthetic photometry from GAIA catalog - Vizier catalog I/360/syntphot [7]. Their typical errors are 0.002 mag. The exception is marked with * and is our measurement. Good agreement (≈ 0.01 mag) between the GAIA magnitudes and our measurements was achieved for stars #1, #3, #4, #5. Using these comparison stars, we measure the B and V magnitudes of GP Com. Journal of observations and the measurements are presented in Table 1.

T a b l e 1

Journal of observations and measured magnitudes

date	telescope	band	UT	N_{pts}	exposure [sec]
2025-04-29	2.0m	V	20:29 – 22:08	22	180
2025-04-30	2.0m	V	18:52 – 00:57	116	180
2025-11-13	1.5m	B	02:42 – 03:48	30	60
		V		30	60
2025-11-14	1.5m	B	02:51 – 03:55	30	60
		V		30	60
2025-11-15	1.5m	B	02:42 – 03:28	21	60
		V		21	60

date	band	min [mag]	max [mag]	average [mag]	stdev [mag]	amplitude [mag]	err [mag]
2025-04-29	V	16.130	16.187	16.1645	0.013	0.057	0.007
2025-04-30	V	16.138	16.200	16.1696	0.013	0.062	0.007
2025-11-13	B	16.051	16.118	16.0771	0.016	0.067	0.010
	V	16.061	16.105	16.0799	0.011	0.044	0.009
2025-11-14	B	16.024	16.078	16.0580	0.015	0.054	0.008
	V	16.032	16.094	16.0664	0.016	0.062	0.007
2025-11-15	B	16.049	16.117	16.0753	0.013	0.068	0.008
	V	16.066	16.102	16.0807	0.010	0.036	0.007

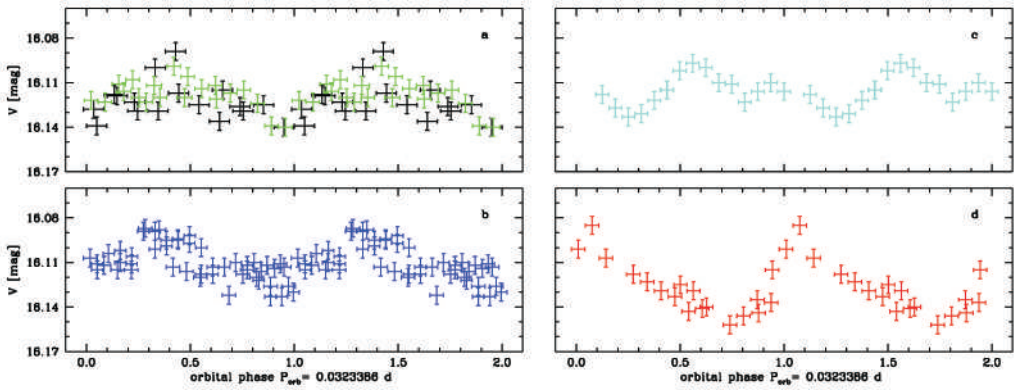


Fig. 2. Orbital variability of GP Com in V band observed with the 2.0m telescope: a) black colour marks the observations on 2025-04-29 from UT20:42 to 22:05, green – those on 2025-04-30 from UT18:52 to 19:59; b) blue colour – observations on 2025-04-30 from UT20:02 to 22:34; c) cyan – 2025-04-30 from UT22:57 to 23:44; d) red – 2025-04-30 from UT23:47 to 00:53. It is visible that the amplitude of the orbital variability is ~ 0.04 mag and the phase of the peak is variable

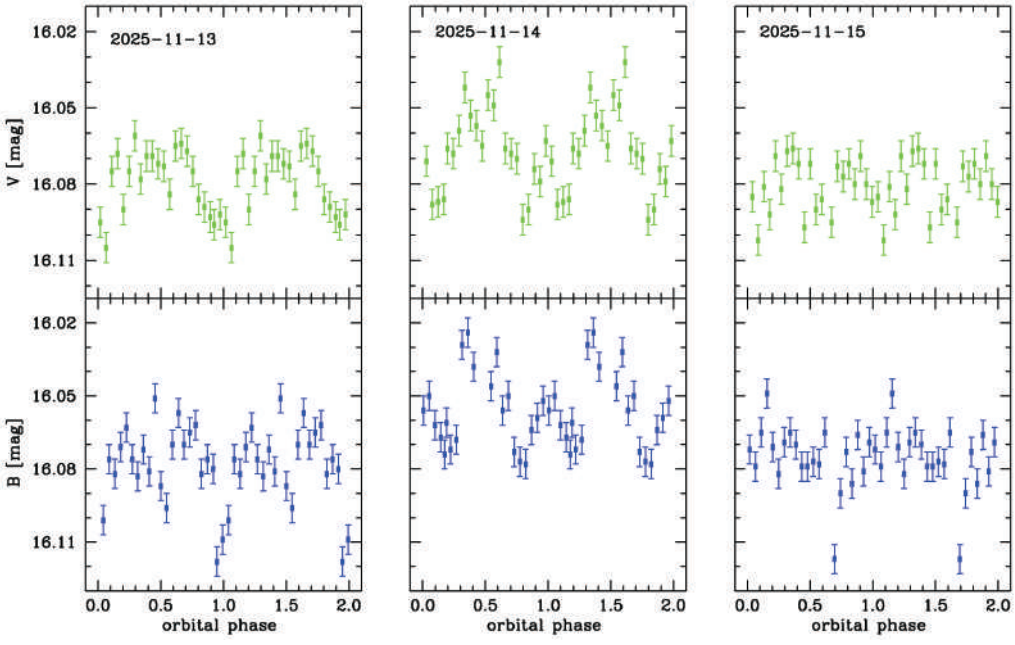


Fig. 3. Simultaneous B- and V-band observations of GP Com obtained with the 1.5m telescope. During the first two nights (2025-11-13 and 2025-11-14) orbital variability with amplitude $\approx$ 0.04 mag is visible in both bands

3. Results. The time-resolved spectroscopy with VLT/ESO [8] gives for GP Com orbital ephemeris HJD = 2452372.5994(2) + 0.0323386E, mass of the primary component $M_1 > 0.33$ $M_\odot$ and mass of the secondary in the range

$9.6 < M_2 < 42.8$ $M_{Jupiter}$ ($0.01 - 0.04$ $M_\odot$). The orbit is inclined to the line of sight at an inclination angle $33^\circ < i < 78^\circ$.

3.1. Orbital modulation in V band. Using this ephemeris, we plot the orbital variability in Fig. 2 and Fig. 3. The observations obtained in April 2025 with the 2.0m telescope are plotted in Fig. 2. They are separated in 4 panels, because the orbital variability is not the same during the different orbital cycles. It is visible that the amplitude of the orbital variability is 0.04–0.05 mag and the phase of the peak is variable.

In Fig. 2a, the black colour marks the observations on 2025-04-29 from UT20:42 to 22:05, and the green colour – those on 2025-04-30 from UT18:52 to 19:59. Although the observations cover 3 orbital cycles from two different nights they have very similar orbital modulation with maximum at orbital phase ~ 0.4. In Fig. 2b (blue colour) are plotted the observations on 2025-04-30 from UT20:02 to 22:34 – the peak is at phase ~ 0.3. In Fig. 2c (cyan colour) are plotted the observations on 2025-04-30 from UT22:57 to 23:44. The peak is at phase ~ 0.5 and a secondary peak at phase ~ 1.0 emerges. In Fig. 2d (red colour) is plotted the next orbital cycle (2025-04-30 from UT23:47 to 00:53) – the peak is at phase ~ 1.0.

The observations obtained with the 1.5m telescope are presented in Fig. 3. During the first two nights (2025-11-13 and 2025-11-14) orbital variability with amplitude ≈ 0.04 mag is visible in B and V bands. During the third night no orbital variability can be seen, probably because the run is shorter.

Our observations show that in the most cases (Fig. 2a,b and Fig. 3) the maximum of the orbital variability is at orbital phase 0.3–0.5. However in Fig. 2c a secondary maximum at phase 1.0 emerges and becomes the only maximum in Fig. 2d. This can be due to azimuthal displacement of the hot spot or appearance of secondary spot (see Sect. 4).

3.2. Binary parameters: is the secondary a white dwarf? The mass ratio of the components in GP Com is $q \approx M_2/M_1 \approx 0.025$ [8]. Adopting their value [8] for the mass of the secondary $M_2 \approx 0.02\ M_\odot$, it will give mass of the primary $M_1 \approx 0.8\ M_\odot$. A well-known property of the white dwarfs is that the more massive white dwarfs are smaller. To estimate the radius of the white dwarf, we use the equation by Eggleton [10]. It gives for the radius of the primary $R_1 = 6970$ km ($0.01\ R_\odot$).

The distance between the components, a, is related to the orbital period by Kepler's third law: $P_{orb}^2 = 4\,\pi^2\,a^3\,[G\,(M_1 + M_2)]^{-1}$. It gives $a \approx 0.40\ R_\odot$. Using the formula [11]: $R_{L2}/a = 0.49\,q^{2/3}[0.6q^{2/3} + \ln(1 + q^{1/3})]^{-1}$ and mass ratio 0.025, we estimate Roche lobe size of the primary $R_{L1} \approx 0.269\ R_\odot$ and of the secondary $R_{L2} \approx 0.054\ R_\odot$. The accuracy of our estimates is connected with the uncertainty of the binary parameters [8], and is of about 5–10%.

The mass transfer in AM CVn stars as well as in cataclysmic variables in general, is via Roche lobe overflow. When the mass transfer has already started,

the Roche lobe size of the secondary is approximately equal to its radius. In other words the radius of the secondary is $R_2 \approx R_{L2} \approx 0.054\ R_\odot$. However, a white dwarf with mass 0.025 $M_\odot$ should have a radius $\approx 0.039\ R_\odot$, which is 1.4 times less than the estimated Roche lobe size. This result indicates that the secondary in GP Com is not a white dwarf, but probably a helium star (the helium core of a former main sequence star).

3.3. Absolute magnitude and mass accretion rate. GP Com has coordinates J2000 RA 13:05:42.4, Dec +18:01:03, corresponding to galactic coordinates 324° +80°. The object is located in direction close to the north galactic pole. In this direction there is no interstellar dust in our Galaxy, and the interstellar extinction to GP Com is zero [9].

Combining our data $16.02 \leq V \leq 16.20$ and $16.02 \leq B \leq 16.12$ (see Table 1) with the GAIA [1] distance (72.7 pc), we find for GP Com absolute V band magnitude in the range $11.7 < M_V < 11.9$ and absolute B band magnitude in the range $11.7 < M_B < 11.8$. Our values are in agreement with the result [12], that GP Com is intrinsically faint, $M_V > 11$.

From the three nights simultaneous B and V band observations with the 1.5m telescope, we find that the maximum brightness is $B = 16.042 \pm 0.014$, $V = 16.053 \pm 0.018$, $B - V = -0.011$. This corresponds to a black body (located at distance 72.7 pc from the Earth) with effective temperature $T = 13200 \pm 200$ K, effective radius $R = 0.011 \pm 0.001\ R_\odot$, and luminosity $L \approx 1.21 \times 10^{31}$ erg s^{-1} (0.0031 L$_\odot$). The optical luminosity of an accretion disc is connected with the mass accretion rate: $L = 0.5 G\ M_1\ \dot{M}_a\ R_1^{-1}$, where G is the gravitational constant, $\dot{M}_a$ is the mass accretion rate, R_1 is the radius of the white dwarf. For a standard accretion disc, the disc luminosity is half of the total accretion luminosity. We calculate mass accretion rate of about $\dot{M}_a = 4.2 \times 10^{-12}$ M$_\odot$ yr^{-1} and 2.5×10^{-12} M$_\odot$ yr^{-1} for $M_1 = 0.6$ and 0.8 M$_\odot$, respectively. These values should be accurate to within a factor of two.

For GP Com a mass accretion rate $\dot{M}_a = 2.3 \times 10^{-11}$ M$_\odot$ yr^{-1} is estimated [13]. Our results indicate 6 to 9 times lower mass accretion rate and are consistent with the predicted mass accretion rate for a cool donor (see [13, Fig. 4]).

3.4. Orbital modulation: temperature of the hot spot. In cataclysmic variables the observed luminosity is a sum of the luminosity of the accreting white dwarf, accretion disc, mass donor, and a hot spot. The mass is transferred in a stream through the inner Lagrangian point to an accretion disc. At the point where the stream impacts the disc, a hot spot is formed. The orbital variability is a result of the hot spot – the maximum is when the hot spot faces the observer.

To calculate the temperature of the hot spot, we first convert the observed magnitudes in fluxes, using the calibration for a zero magnitude star $F_0(B) = 6.13268 \times 10^{-9}$ erg cm^{-2} s^{-1} Å^{-1}, $\lambda_{\rm eff}(B) = 4371.07$ Å, $F_0(V) = 3.62708 \times 10^{-9}$ erg cm^{-2} s^{-1} Å^{-1} and $\lambda_{\rm eff}(V) = 5477.70$ Å as given in the Spanish virtual observatory Filter Profile Service [14]. Adopting that the orbital variability is due to the hot

spot, we calculate the contribution of the hot spot as: $F_{hs} = F_{\max} - F_{\min}$, where F_{hs} is the flux emitted by the hot spot, $F_{\max}$ and $F_{\min}$ are maximum and minimum of the observed flux during the night. They are estimated using the minimum and maximum magnitudes during the night (see Table 1) after correction for the observational errors and the scatter of the brightest and faintest points. To calculate the temperature, we use the calibration for the $(B-V)$ colour of a black body [15, Table 18], and find temperature of the hot spot $T = 24700 \pm 4000$ K and $T = 13350 \pm 3000$ K for our observations on 2025-11-13 and 2025-11-14, respectively. Our results indicate that the hot spot is probably a few $\times 1000$ K hotter than the value assumed in [13], and give a clue why they estimated a higher mass accretion rate. On 2025-11-14 the star is brighter than on 2025-11-13, and the hot spot has a lower temperature. This can be a result of the fact that in a brighter state the spot expands and its temperature decreases (more details can be found in Sect. 2.3 [16], where a model of accretion disc is developed).

4. Discussion. It was suggested [2] that GP Com's disc is on the lower branch of the thermal instability curve and does not undergo the global outbursts followed by intervals of mass accumulation as occur in dwarf novae. However, recently one outburst was found in the archival historical data from 1950–1951 [17]. This means that the outbursts are rare, probably as a result of the low mass accretion rate ($\approx 3 \times 10^{-12}$ $M_\odot$ yr^{-1}, see Sect. 3) and as a consequence a long time (probably a few decades) were needed for mass accumulation.

The Doppler tomography of GP Com [7] detected a strong bright spot near the expected accretion stream/disc impact region, with a faint secondary bright spot at $\sim$ 120-degree phase-offset. The presence of a second bright spot in the accretion disc was also found in SDSS J120841.96+355025.2 ($P_{orb} = 52.9$ min) [18]. In cataclysmic variables the hot spot must move around, both azimuthally and radially, as the accretion disc and accretion rate change [19]. The accretion flow originating from the inner Lagrangian point probably has variable direction and velocity. In this way it strikes the accretion disc at different positions. Do the strong bright spot and the faint secondary bright spot (see also Sect. 3) exist simultaneously or in some orbital cycles exists only one of them is a question that should be addressed in future work.

Conclusions. We report 10.6 hours photometric observations of the ultra-short period binary GP Com, consisting of a white dwarf and the helium core of a former main sequence star. The observations are obtained with the telescopes of Rozhen National Astronomical Observatory. We find an orbital modulation with amplitude 0.04–0.05 mag in B and V bands and variable orbital phase of the maximum. We estimate temperature of the bright spot $\approx 19700 \pm 3000$ K and mass accretion rate of about 2×10^{-12} $M_\odot$ yr^{-1}, consistent with the predicted rate for a cool donor.

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